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Modeling the Transmission of Wolbachia in Mosquitoes for controlling Mosquito-borne Diseases

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We develop and analyze a differential equation model to quantify the effectiveness of creating a sustained infection of Wolbachia bacteria in wild mosquitoes. Wolbachia is a natural parasitic microbe that can reduce the ability of mosquitoes to spread mosquito-borne viral diseases such as dengue fever, chikungunya, and Zika. It is difficult to sustain an infection of the maternal transmitted Wolbachia in a wild mosquito population because of the reduced fitness of the Wolbachia-infected mosquitoes and cytoplasmic incompatibility limiting maternal transmission. The infection will only persist if the fraction of the infected mosquitoes exceeds a minimum threshold. Our model captures the complex maternal transmission cycle, which accounts for heterosexual transmission, multiple pregnant states for female mosquitoes, and the aquatic-life stage. We identify important dimensionless numbers and quantify the critical threshold condition for obtaining a sustained Wolbachia infection in the natural population. This threshold effect involves a backward bifurcation with three coexisting equilibria of the system of differential equations: a stable disease-free equilibrium, an unstable intermediate-infection endemic equilibrium, and a stable high-infection endemic equilibrium. We are extending the differential equation model to account for the spatial heterogeneity of the Wolbachia infection when mosquitoes are released into the wild to better understand when local highly infection region will grow or shrink.